



HISTORICAL LEAD OPERATIONS

GLOBE PLANT DENVER, COLORADO

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ASARCO Incorporated

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EnviroGroup Limited

The environmental solutions company

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**HISTORICAL LEAD OPERATIONS
GLOBE PLANT
DENVER, COLORADO**

Introduction

This document provides a summary of lead smelting and refining operations that have been conducted at the Globe Plant since its inception in 1886 through the present day. The Globe Plant was initially constructed as a lead smelter, known at that time as the Holden Smelter. The history of the subsequent lead operations can best be described by looking at four general time periods, as follows:

- 1886-1890: This time period is characterized by the early lead blast furnace operations, including initial construction of the plant and subsequent growth of the facilities to include 7 blast furnaces and 10 hand roasters.
- 1891-1904: Significant increased growth of the facilities occurred during this time period under the supervision of Dr. Malvern Iles, an accomplished metallurgist¹, including construction of a large baghouse to collect all of the blast furnace fumes (the "Bartlett Process"), the addition of several more roasters and a major flue system connecting all the roasters to a common stack, and the construction of a silver and gold refinery. Most of these developments occurred during the 1890's. The American Smelting and Refining Company purchased the Globe Plant in 1899.

¹According to Fell (1979), "Iles, drawing upon his great experience and his knowledge of the latest advances in technology, designed an integrated smelter that was to be the most efficient of its day, a reputation held well into the twentieth century" (p.109).

- 1905-1919: Under the ownership of the American Smelting and Refining Company, the Globe Plant underwent significant additional expansion and modernization during this time period, until lead smelting operations ceased in 1919. Processes for the recovery of arsenic and cadmium from lead smelter baghouse dust were initially developed during this time period.
- 1920-1998: After the lead smelting operation was shut down in 1919, arsenic trioxide refining (1920 to 1926) and cadmium refining (1927 to 1993) were the principal operations conducted at the plant. However, litharge (lead oxide) and test lead refining have been conducted on a small scale since the litharge department was moved from Pueblo to the Globe Plant in 1925 and continues to the present.

The general nature and layout of the facilities during each of these time periods are shown on Figures 1 through 7 (Figures 4 through 7 cover the 1920 to 1998 time period). The maps on Figures 1 through 7 were based on various historic maps; key source maps and historic engineering drawings are included in Attachment A. The following sections discuss the facilities and operations during each time period in more detail.

1886 to 1890 Time Period

Malvern Iles, one of the original partners of the Holden Smelting Company, began construction of the Holden Smelter (later re-named the Globe Smelter) in May of 1886; the first smelting furnace was set to blast in September, the second and third in October, and the fourth in December 1886 (Fell 1979, p. 149). The blast furnaces were located in a single building along the edge of the terrace (see 1886 to 1890 map, Figure 1). By the end of 1886, the four furnaces at the Holden smelter could process up to 175 tons/day of lead ore (EMJ 43, p.10) and had produced 2,908,401 lbs of lead bullion (EMJ 43, p.28). Two more blast

furnaces were added in the spring of 1887(EMJ 43, p.100), bringing the total to six with a plant capacity of 300 tons of ore per day (Fell 1979, p.150).

In 1887, the Holden Smelting Company was taken over by one of the original investors, Dennis Sheedy of the Colorado National Bank. Sheedy reorganized the firm as the Globe Smelting and Refining Company and expansion of the plant continued under the direction of Dr. Iles (Fell 1979, p.151). By 1890 seven blast furnaces were in place (see Attachment A, 1890 Sanborn Map), bringing the total smelting capacity to 350 tons of ore per day.

The blast furnace emissions were vented to a single 125 foot tall brick stack at the northwest corner of the blast furnace building (see Attachment A, 1905 Globe Smelter Map for table of stack heights). In the summer of 1888, the dust chamber conveying fumes from the blast furnaces to the stack was extended 205 feet north of the building and then back to the stack, to settle out more of the dust (EMJ 46, p.134). According to Iles (1902, p.188), this extension of the dust chamber increased recovery of lead in the flue dust.

Six hand roasters were originally installed in Roaster Building No. 1 (see Figure 1) to reduce the sulfur content of high sulfide ores prior to smelting, giving the plant a total roasting capacity of approximately 75 tons/day (EMJ 43, p.100). Four additional hand roasters with 12 ton/day capacities were installed in Roaster Building No. 2 by early summer of 1887 (EMJ 43, p.425). During this time period, emissions from Roaster Building Nos. 1 and 2 were controlled by an 80 foot and an 87 foot tall brick stack, respectively.

The Globe Smelter produced 19,485,577 pounds of lead bullion in 1887 and 23,373,167 pounds of bullion in 1888.

1891 to 1904 Time Period

Expansion of the lead smelting operations continued during the 1890's under the direction of Dr. Iles (Figure 2). Three reverberatory furnaces were added to the east of the blast furnace building to enhance separation of the matte and slag drawn from the blast furnaces. These furnaces kept the mixture of matte and slag in a liquid state until separation was completed and the matte could be drawn off for re-smelting and further recovery of metals (Pufhal 1905). The slag was sent to the slag pile east of the terrace (e.g., see Attachment A, 1890 Sanborn Map). Fumes from the reverberatory slag furnaces were controlled by the baghouse (Iles 1902, p.203-204).

The number of blast furnaces was not increased from the original seven; however, one of the most significant additions was the construction of a 1200 foot long flue and baghouse in 1891, which controlled blast furnace fumes from that time forward. Known as the "Bartlett Process", the motivation for the baghouse was largely economic, as the dust collected in the baghouse contained significant concentrations of lead and silver. According to Iles (1902):

"[T]he smoke loss each day of 24 hours was 25,712 pounds, or 12.856 tons. This, at a lead assay of 60 per cent. and a silver valuation of 3.5 ounces, gives 7.7136 tons of lead and 44.99 ounces silver that would be lost in the fume from seven blast-furnaces in one day, or an aggregate of \$139,758.50 in one year. When smelting at the rate of 500 tons daily the annual loss of silver and lead will aggregate \$150,000 to \$175,000 per year. This is not a theoretical calculation, but based on carload lots of burnt bag-house fume, carefully weighed and sampled" (p.159).

Prior to the construction of baghouses, Iles reports that 8 to 16 percent of the lead (in ore) was lost per year in blast furnace smoke; based on tests at the Globe Smelter, 7 to 12

tons of metallic lead were lost per day (p.188). Iles (1902, p.210) reported that of the total smoke from the blast furnaces, 37 percent was dust that settled in the dust chambers and flues, and 63 percent was fume that was collected by the baghouse (and presumably escaped prior to installation of the baghouse).

Several of the original engineering drawings for the Bartlett Process baghouse are included in Attachment A, showing plan views and elevations of the building; the number and orientation of the bags; and the fan and flue system conveying blast furnace gases to the baghouse. The original baghouse built in 1891 (Baghouse No.1) contained eighteen "rooms" with 81 bags per room, for a total of 1,458 bags. Each bag was 18 inches in diameter when extended and 30 feet long. The "ventilators" through which gases exited the building were approximately 55 to 60 feet above the ground, at the apex of the roof.

Iles (1902) provides a detailed discussion of the operation of the baghouse. The fans and flues were sized to handle 220,000 cfm of gas (Iles 1902, p.189). The temperature of the smoke was kept below 300 °F at the baghouse to prevent burning of the bags; according to Iles "the pyrometer is read every hour, night and day, to prevent burning the bags and setting the fume on fire". Iles recommended having sufficient bag capacity to allow shaking once per day, although in hot weather he recommended shaking twice daily to reduce the number of spontaneous fume fires (in the flues and bins underneath the baghouse). Iles does not provide any indication that the fume fires caused any damage to the bags. In fact, the fume was intentionally burned in the fume-rooms underlying the baghouse to fuse the material prior to re-smelting; when the fumes in certain rooms were being burnt, the overlying bags were unused to avoid undue strain on the bags (p.198).

The gases passing through the bags vented through "ventilators" or horizontal slats near the apex of the roof; however, the doors and windows were left open in hot weather for additional ventilation (p.201). In damp weather, Iles recommended keeping doors and

windows closed, except when the bags were being shaken. According to Pufhal(1905), the bags were shaken every 6 hours. Iles conducted experiments to determine both the best type of cloth to use and the effects of varying gas temperatures on the cloth integrity. Based on the detailed nature of his discussion on the baghouse operation, sensitivity to the economic losses associated with lead and silver values in fume, concern over cloth material, and efforts to prevent burning of the bags by controlling gas temperature, it appears the facility was well monitored and maintained. Although Iles states that the bag "cloth rarely gives way" (p.202), any damaged bags would have been noticed during daily (or more frequent) hand shaking and were likely repaired in short order.

The roasting capacity of the Globe Smelter was greatly increased during the 1890's, including the addition of five more hand roasters in Roaster Building No. 2, installation of two mechanical Brown-O'Hara roasters, each with a 26 ton/day capacity, and 12 Bruckner roasters with approximate capacities of 8 tons/day each (Pufahl 1905). Also during this time period, all of the roasters except Roaster Building No. 1 were connected by brick flues to a common 152 foot stack at the northern boundary of the property (Figure 2). Roaster Building No. 1 was not connected to the common stack during this time period, likely because the hand roasters in this building were destined to be removed and replaced with a newer roasting process (see 1905 to 1919 time period). Roaster fumes could not be collected by the baghouse because the sulfuric acid generated by roasting of the sulfide ores would corrode the bags (Iles 1902, p.166).

Iles (1900) provides a comparison of the costs of hand roasting versus mechanical roasting in the Brown-O'Hara furnaces, based on cost data from 1887 to 1898. A blue print of the Brown-O'Hara roaster building is included in Attachment A. Iles indicates that the mechanical furnaces were originally introduced as a lower cost method of roasting, rather than just for increasing total roasting capacity. The total tons roasted per month and per day (on average) at the Globe Smelter for 1898 are provided in Iles (1900). In his 1902

treatise on lead smelting, Iles opines that "Bruckner roasters are destined to play an important part at lead-smelters for roasting the sulfide ores" but has little to say about their operation or costs, suggesting that the 12 Bruckner roasters first shown on a 1903 Globe Plant map of the works (traced from an earlier undated drawing) were only recently installed.

Iles (1902) also provides a significant amount of information on the roaster emissions, including test data on smoke from Roaster Buildings Nos. 1 and 2. For example, in tests of different types of bag materials for capturing roaster fumes, Iles reports that the combined volume of smoke from the two roaster stacks was 75,714 cubic feet per minute (cfm), with an average velocity in the dust chambers of 529 feet per minute (fpm). The temperatures at the bases of these stacks ranged between 600 and 750 °F. This resulted in a calculated fume loss of 1140 tons per year, which assayed at 40.20 percent lead (average of three experiments). Tests on the Brown-O'Hara mechanical roasters indicated a smoke volume of 56,800 cfm and a velocity of 1420 fpm in the flue; in two experiments, the fume contained 16 to 45.2 percent lead. The temperature at the base on the sheet-iron stack was 1375 °F. These data apply to the stacks controlling smoke from the individual roaster buildings prior to installation of the long flue and common stack. Finally, Iles states that it is possible to save most of the dust from roasters, using long dust chambers or flues and smoke velocities in the range of 200 to 400 fpm, but that lead losses from fumes vary from 2 to 7 percent of the total lead in the ore roasted (p. 176). It is likely that the latter comments are based, in part, on observations of the long flue and common stack that was constructed during the 1890's to control roaster smoke (see Figure 2). A three-dimensional drawing of the flue system and common stack is contained in Attachment A.

A refinery was built at Globe in 1892-93 to recover silver and gold from lead bullion (Fell 1979, p.153; EMJ 54, p.62). With a planned capacity of 80 tons of bullion per day, the refinery required bullion from other smelters as far away as Mexico and Washington (Fell

1979, p. 153). The fumes from the silver and gold melting and other refining furnaces were controlled by the baghouse (Iles 1902, p.204).

1905 to 1919 Time Period

Under the ownership of the American Smelting and Refining Company, the Globe works underwent a new era of development beginning in 1905 (Figure 3). Lead smelting continued using seven blast furnaces and an expanded baghouse until the operation was shut down in 1919; however, two extensions of the baghouse building increased the number of bags to 2,789. Tests conducted circa 1907 indicate that the baghouse controlled 160,000 cfm of gas when all seven blast furnaces were in operation, with gas temperatures of 130°F to 150°F. The bags provided an air-to-cloth ratio of 390,000 sf/cfm, which was characterized as being "more than ample" (see table of Bag House data, Attachment A).

Other than expansion of the baghouse, the principal changes to the lead smelting operation during this time period were the introduction of the Huntington-Heberlein roasting process and Dwight & Lloyd sintering machines, which replaced most of the older and less efficient hand roasters (see Figure 3). Based on a 1905 site map (see Attachment A) the silver and gold refining process was shut down by 1905 and the former refinery building was used for certain operations associated with arsenic trioxide refining and, to a limited extent, cadmium refining, which were both developed during this time period.

The Heberlein roasters used in the Huntington-Heberlein process were installed in Roaster Building No. 1, replacing the original hand roasters in this building (see Figure 3 and Attachment A, General Design and Location of the Huntington-Heberlein Process). The patented process involved roasting sulfide ores with limestone at relatively low temperatures. The roasted ore was allowed to cool, placed in pots over a small quantity of red-hot calcines from the roasting furnace, then subjected to an air blast. The resulting

chemical reaction within the roasted ore generated sufficient heat to drive off sulfur dioxide without further addition of heat (Ingalls 1906). According to Ingalls (1906), the Huntington-Heberlein process increased lead recovery in ore from about 90 to 92 percent for standard reverberatory furnaces (such as hand furnaces) to about 98 percent, representing a 75 to 80 percent reduction in the amount of lead volatilized. This was largely due to the lower temperatures required for roasting by this process and the resultant decrease in the volatilization of lead oxide. The eight Heberlein roasters each had a capacity of about 40 tons of ore per day (Ingalls 1906). The Huntington-Heberlein process also resulted in treated ore that was more efficiently smelted, increasing the production rate of the blast furnaces by 60 to 100 percent.

Dwight & Lloyd Sintering Machines were installed in Roaster Building No. 2, replacing three of the original hand roasters (Figure 3). These mechanical roasters fused or sintered the ore and dusts being roasted more efficiently, resulting in superior properties for subsequent blast furnace smelting. The gases from the Dwight & Lloyd sintering machines was conveyed through the existing flue system to the common stack at the north end of the property.

During this time period, significant changes were made to the plant to allow recovery of arsenic trioxide from lead smelter baghouse dust (e.g., see 1905 Globe Plant Site Map). To summarize the process, one of the hand roasters in Roaster Building No. 2 was replaced with a mechanical roaster dedicated to the arsenic refining process; fumes from this roaster were routed through a new set of "black arsenic flues", where arsenic trioxide sublimated onto the walls and floors of the flues as the gases cooled. Gases leaving the kitchen were collected in the first 11 rooms of the baghouse, which were dedicated to the arsenic operation after 1912. In addition, an arsenic refinery was constructed, consisting of two furnaces and a second set of flues known as the "white arsenic kitchens", which re-roasted the lower grade arsenic trioxide from the black kitchens to produce 95 to 99.9 percent pure

arsenic trioxide (e.g., see Carapella 1964). Gases that left the white arsenic kitchens were also controlled by the baghouse. Because the arsenic refining process resulted in fumes that were almost entirely arsenic trioxide, these operations would not have been a significant source of lead emissions. Further, any of the arsenic refining fumes that left the kitchens or flues were controlled by the baghouse.

Recovery of cadmium from lead smelter baghouse dust was also conducted on a limited scale during the 1905 to 1919 time period (according to an August 20, 1926 memo by Roscoe Teats, the Globe Plant superintendent, large stocks of cadmium dust had been on hand for many years, suggesting it was largely accumulated during prior time periods). As shown on the 1905 Globe Plant Map, a cadmium calcining furnace was located in the former silver and gold refinery building, and a cadmium plant was installed in the former silver and gold parting plant. When cadmium concentrations in the baghouse dust reached sufficient levels (e.g., 40 percent according an April 1, 1928 Globe Plant document entitled "Outline of Cadmium Process"), the dust was treated in the calcining furnace by mixing with sulfuric acid and heating to force lead and other metals into insoluble forms, while the cadmium remained soluble as cadmium sulfate and could be leached from the resulting calcines. As a result, the calcining operation is unlikely to have had significant lead emissions; this conclusion is supported by concentrations in gas cleaning liquids from modern day calcining operations, which are very low in lead (see TRC 1988, Table 3.7).

1920 to 1998 Time Period

Production of litharge (lead oxide) and test lead were the only significant lead operations at the Globe Plant after the lead smelting operation shut down in 1919. The litharge plant was moved from Pueblo in 1925 and has operated at the Globe Plant since that time (see Figure 5, 6, and 7 for the 1927 through 1998 time periods). Emissions have been directly measured by stack tests in recent years for the four baghouses that now

control emissions from the Litharge Department (TRC 1989).

Arsenic trioxide production, the principal operation at the Globe Plant from 1920 through 1926, would not have produced significant lead emissions, as discussed in the previous section. Further, all arsenic trioxide production emissions were controlled by the baghouse (see Figure 4, 1920 through 1926).

Cadmium refining (production of cadmium metal, cadmium oxide, and cadmium powder) was the principal operation at the Globe Plant after the arsenic trioxide operations shut down, from 1927 to until the cadmium circuit was shut down in 1993 (small scale cadmium operations have continued in the high purity laboratory since 1993). As discussed earlier, calcining and subsequent refining steps in the cadmium process should not have contributed significant lead emissions, because lead was removed from the process by precipitation during the calcining process.

Some lead emissions would have resulted from roasting of cadmium dust and lead-containing calcine residues, which was conducted in the Godfrey Roaster Building as a method of increasing cadmium concentrations in the dust and recovering cadmium lost to residues. According to the 1928 "Outline of Cadmium Process" document, the cadmium dust collected in the baghouse contained 5 to 15 percent lead. Initially, Godfrey Roaster emissions were controlled by the original baghouse for the lead blast furnaces (Figure 4, 1927 through 1930). The original baghouse was replaced in 1948 by a new baghouse (e.g., see Figure 5, 1931 through 1948), which was used to control Godfrey Roaster emissions until the roaster was shut down in 1977.

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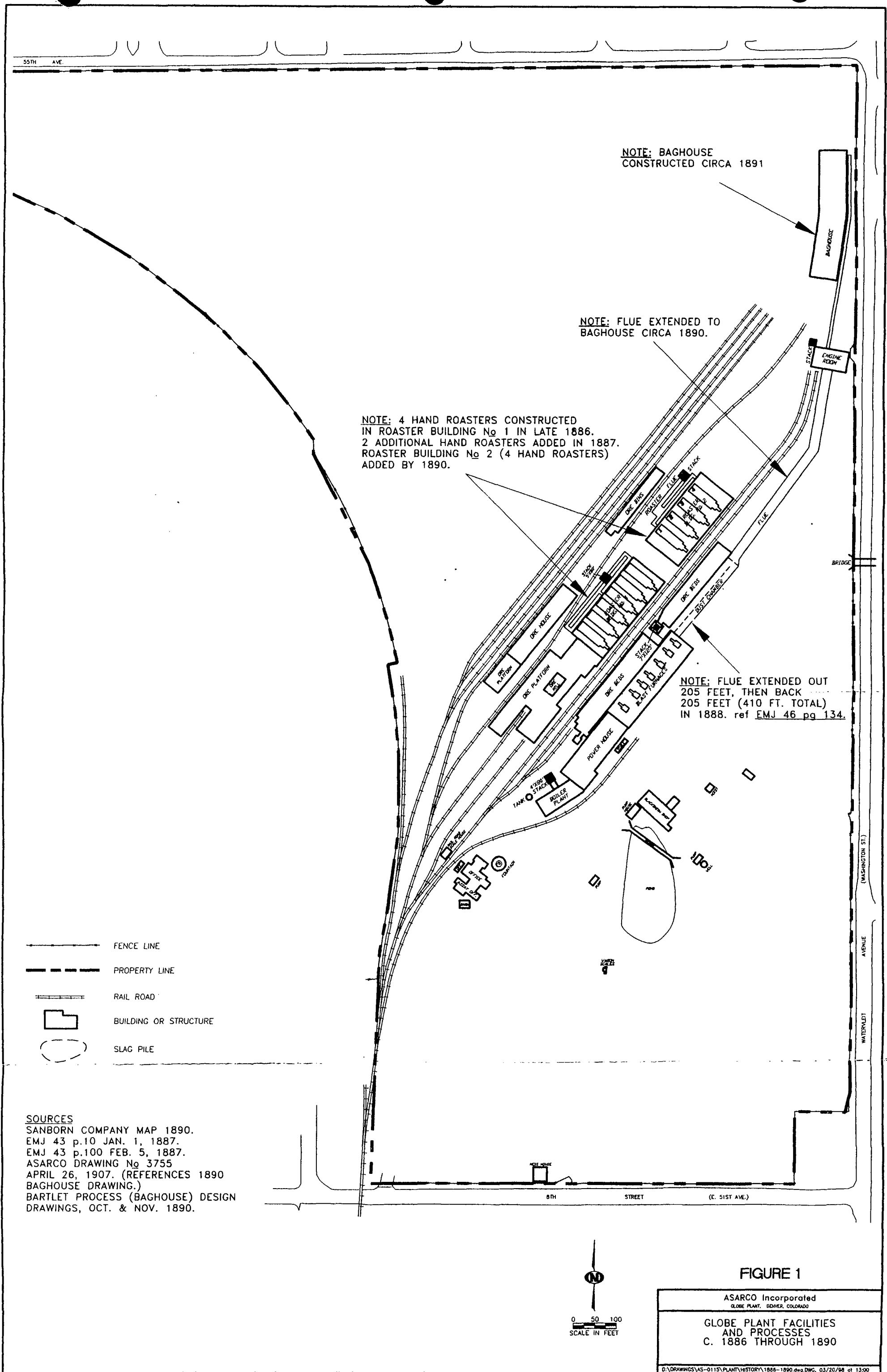
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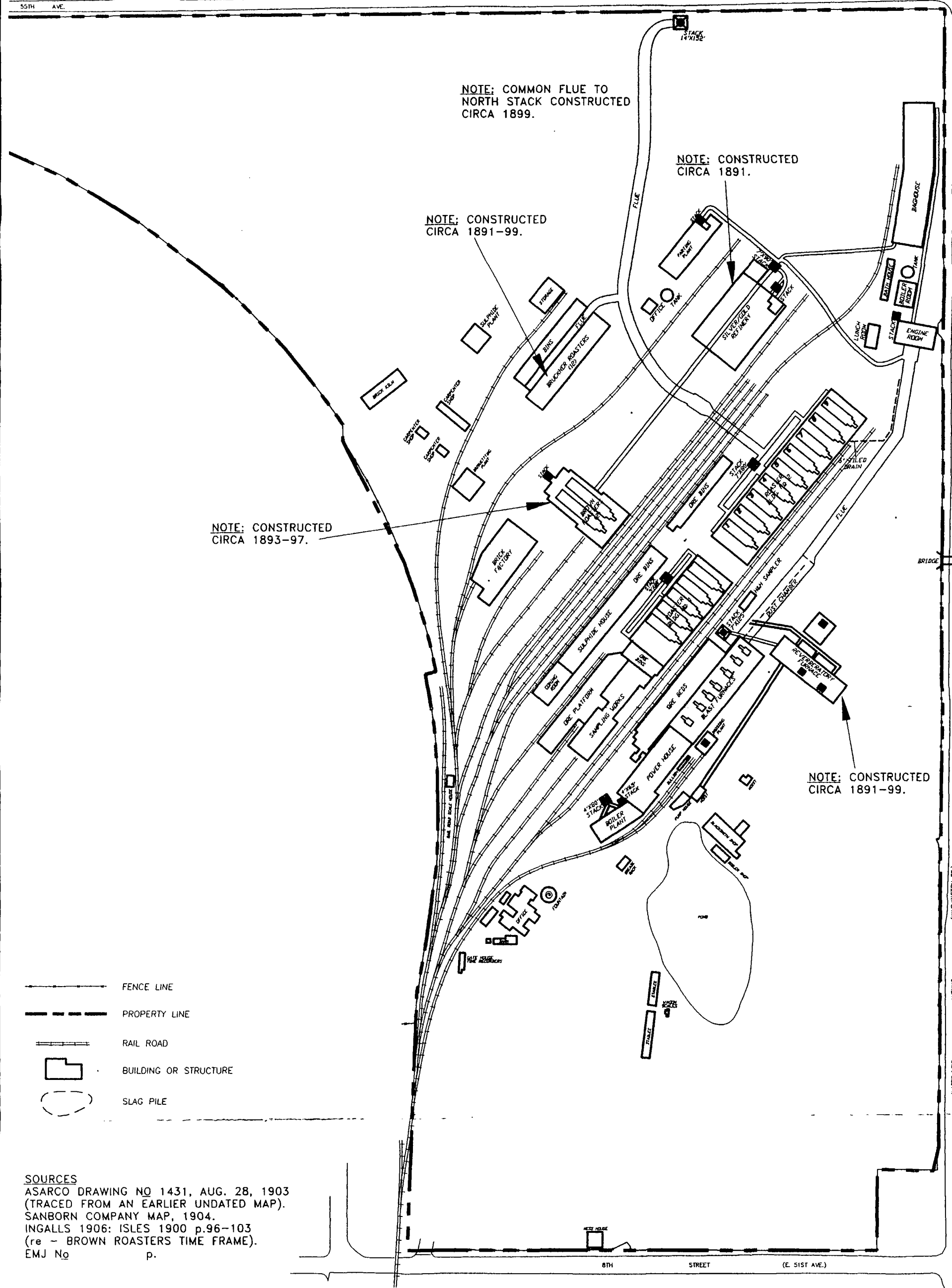
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- FENCE LINE
- - - PROPERTY LINE
- RAIL ROAD
- BUILDING OR STRUCTURE
- SLAG PILE

SOURCES
 ASARCO DRAWING NO 1431, AUG. 28, 1903
 (TRACED FROM AN EARLIER UNDATED MAP).
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 (re - BROWN ROASTERS TIME FRAME).
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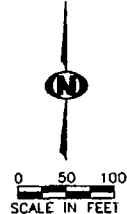
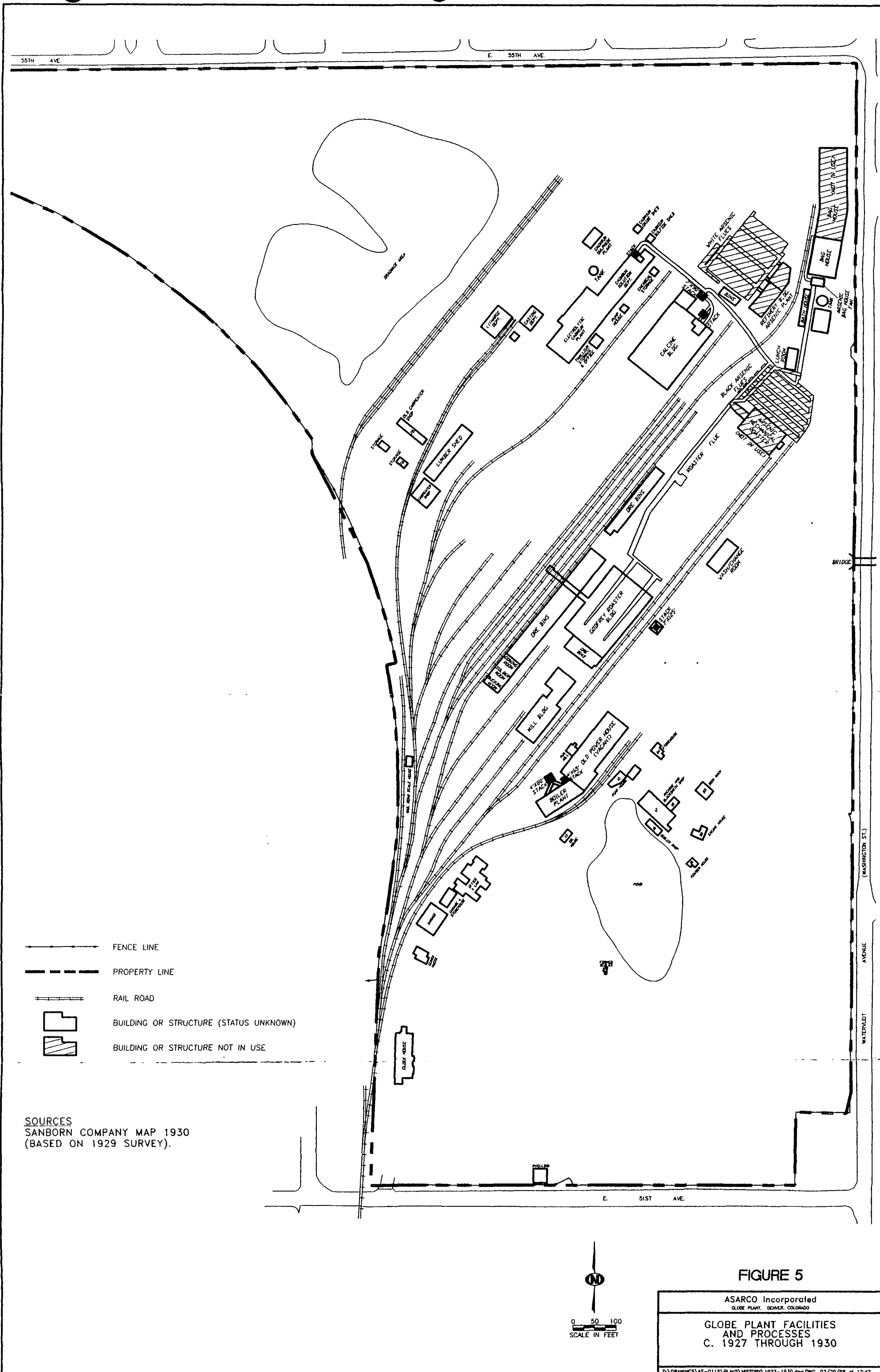
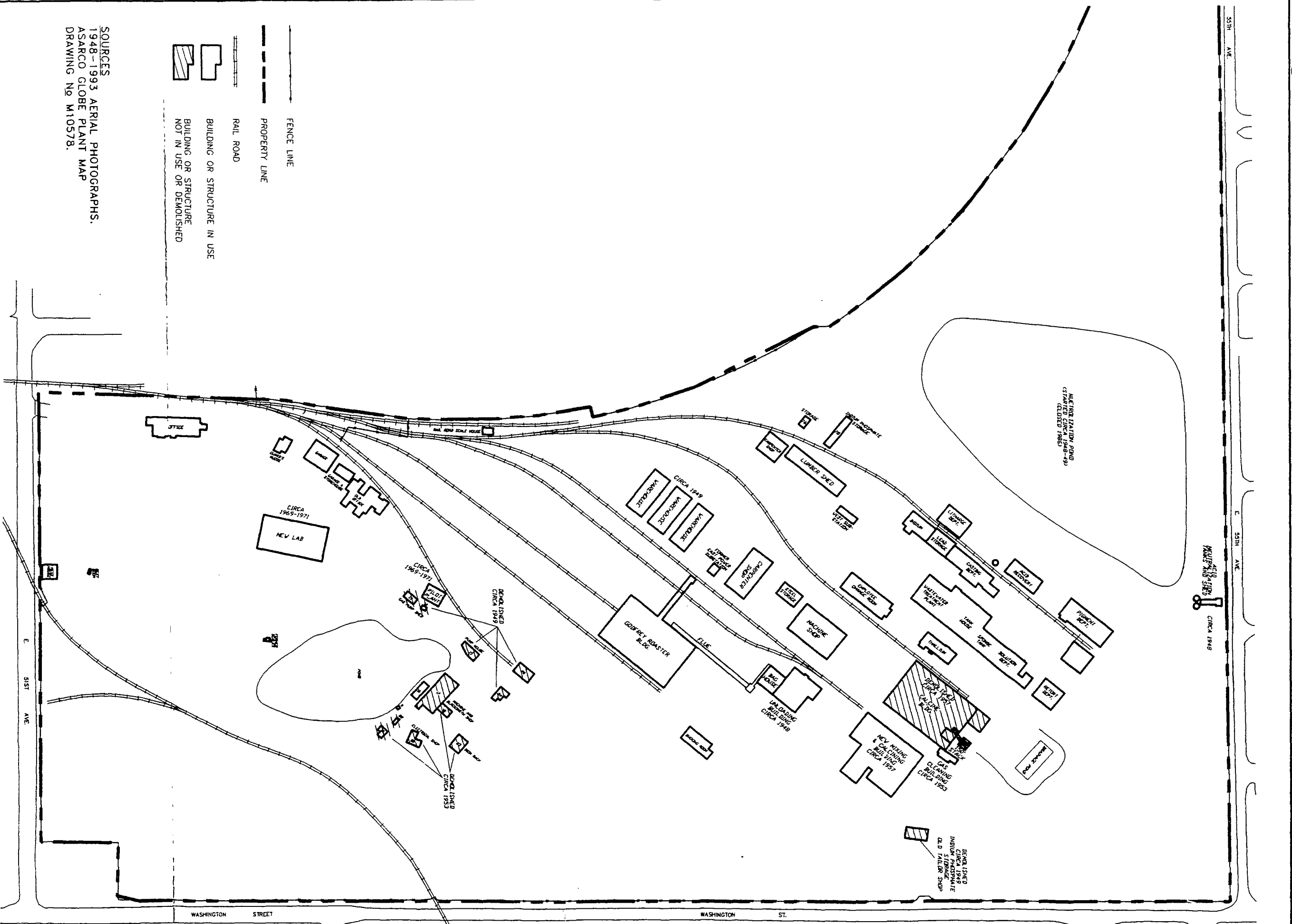


FIGURE 2

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 GLOBE PLANT, DENVER, COLORADO

**GLOBE PLANT FACILITIES
 AND PROCESSES
 C. 1891 THROUGH 1904**





SOURCES
1948-1993 AERIAL PHOTOGRAPHS.
ASARCO GLOBE PLANT MAP
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DOCUMENT DESCRIPTION:

ATTACHMENT A - 18 Plant Drawings (See Table of Contents)

